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Long-Term Outcomes of Pectoralis Major Transfer for the Treatment of Irreparable Subscapularis Tears: Results After a Mean Follow-up of 20 Years

Ernstbrunner, Lukas ; Wieser, Karl ; Catanzaro, Sabrina ; Agten, Christoph A ; Fornaciari, Paolo ; Bauer, David E ; Gerber, Christian

Abstract: BACKGROUND One recognized salvage option in the treatment of an irreparable subscapularis tear is the pectoralis major tendon transfer (PMT). We aimed to analyze the long-term clinical and imaging outcome of PMT for irreparable subscapularis deficiency. METHODS Twenty-eight consecutive patients representing 30 shoulders underwent PMT at a mean age of 53.0 years (range, 35 to 67 years). At a mean of 19.7 years (range, 18 to 22 years) postoperatively, 24 shoulders (80%) were clinically examined and 21 were radiographically and sonographically assessed. The long-term results were compared with preoperative findings and previously published short-term results. RESULTS The mean relative Constant score (percentage of age and sex-matched normal scores; CS%) and the Subjective Shoulder Value (SSV) both improved significantly from preoperatively (CS%, 47%, and SSV, 22%) to postoperatively (CS%, 77%, and SSV, 71%; $p < 0.001$ for both). All patients rated their results as good or excellent. Active anterior elevation was improved from preoperatively (120°) to postoperatively (131°), but the difference was not significant. Active internal and external rotation decreased significantly from the short-term (32-month) follow-up to the time of the latest follow-up ($p = 0.005$ and $p = 0.002$, respectively); however, internal rotation remained at 6 points compared with the 8 points recorded at short-term follow-up and external rotation decreased only from a mean of 51° to 39°. Loss of active range of motion was not observed subjectively and was not subjectively limiting, represented by the high ultimate SSV and overall satisfaction. Four shoulders (19%) showed evidence of glenohumeral arthropathy (Samilson and Prieto grade 3), but clinically were mildly symptomatic to asymptomatic at the time of the latest follow-up (CS% range, 67% to 88%; SSV range, 70% to 80%). Rupture of the PMT was sonographically identified in 2 patients (10%) and was associated with radiographic evidence of advanced cuff tear arthropathy (Hamada stages 4). Six (20%) of the initial 30 shoulders were revised, and 1 (4%) of the 24 shoulders that were clinically examined underwent reverse total shoulder arthroplasty. CONCLUSIONS At long-term follow-up, PMT for isolated and combined subscapularis tears is associated with good to excellent clinical results. Although one-third of the shoulders developed mildly symptomatic or asymptomatic osteoarthritis, the need for salvage with use of reverse total shoulder arthroplasty was rare. LEVEL OF EVIDENCE Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Long-Term Outcomes of Pectoralis Major Transfer for the Treatment of Irreparable Subscapularis Tears

Results After a Mean Follow-up of 20 Years

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Investigation performed at the Balgrist University Hospital, Zurich, Switzerland

Background: One recognized salvage option in the treatment of an irreparable subscapularis tear is the pectoralis major tendon transfer (PMT). We aimed to analyze the long-term clinical and imaging outcome of PMT for irreparable subscapularis deficiency.

Methods: Twenty-eight consecutive patients representing 30 shoulders underwent PMT at a mean age of 53.0 years (range, 35 to 67 years). At a mean of 19.7 years (range, 18 to 22 years) postoperatively, 24 shoulders (80%) were clinically examined and 21 were radiographically and sonographically assessed. The long-term results were compared with preoperative findings and previously published short-term results.

Results: The mean relative Constant score (percentage of age and sex-matched normal scores; CS%) and the Subjective Shoulder Value (SSV) both improved significantly from preoperatively (CS%, 47%, and SSV, 22%) to postoperatively (CS%, 77%, and SSV, 71%; $p < 0.001$ for both). All patients rated their results as good or excellent. Active anterior elevation was improved from preoperatively (120°) to postoperatively (131°), but the difference was not significant. Active internal and external rotation decreased significantly from the short-term (32-month) follow-up to the time of the latest follow-up ($p = 0.005$ and $p = 0.002$, respectively); however, internal rotation remained at 6 points compared with the 8 points recorded at short-term follow-up and external rotation decreased only from a mean of 51° to 39°. Loss of active range of motion was not observed subjectively and was not subjectively limiting, represented by the high ultimate SSV and overall satisfaction. Four shoulders (19%) showed evidence of glenohumeral arthropathy (Samilson and Prieto grade 3), but clinically were mildly symptomatic to asymptomatic at the time of the latest follow-up (CS% range, 67% to 88%; SSV range, 70% to 80%). Rupture of the PMT was sonographically identified in 2 patients (10%) and was associated with radiographic evidence of advanced cuff tear arthropathy (Hamada stages ≥4). Six (20%) of the initial 30 shoulders were revised, and 1 (4%) of the 24 shoulders that were clinically examined underwent reverse total shoulder arthroplasty.

Conclusions: At long-term follow-up, PMT for isolated and combined subscapularis tears is associated with good to excellent clinical results. Although one-third of the shoulders developed mildly symptomatic or asymptomatic osteoarthritis, the need for salvage with use of reverse total shoulder arthroplasty was rare.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Isolated tears of the subscapularis tendon are rare and often misdiagnosed[1]. They can be associated with pain and loss of internal rotation[2,3]. Subscapularis tears as part of a massive tear (≥2 tendons)[4] can be associated with pseudoparalysis, especially if the inferior part of the subscapularis is torn[5-7]. Successful repair of acute subscapularis tears has been reported[2,6]. The success of the procedure depends on the preoperative quality of the musculotendinous unit and, specifically, the degree of fatty infiltration of the muscle[8-10].

Tendon transfers are a viable option to restore shoulder function and prevent progression of degenerative joint disease in shoulders with irreparable rotator cuff tears. Pectoralis major tendon transfer (PMT) has been reported as 1 option for

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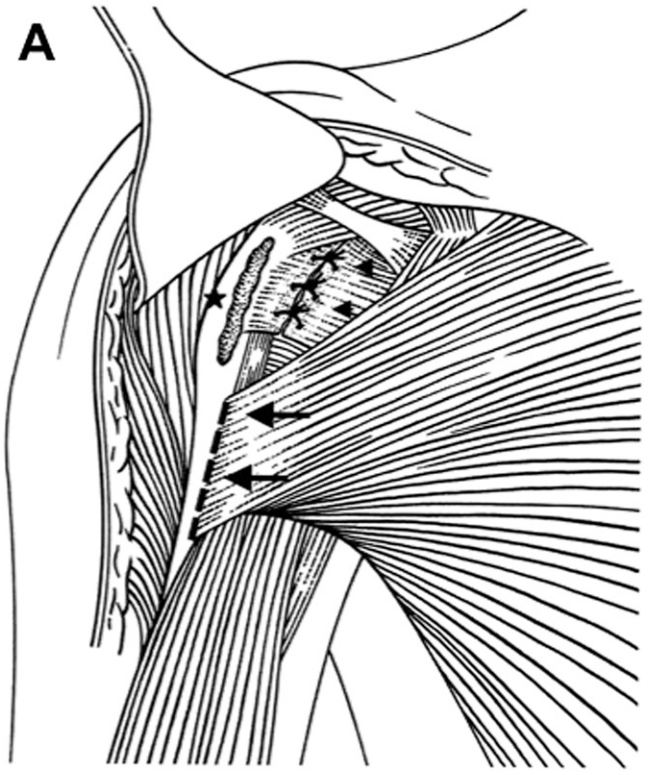

Fig. 1-A

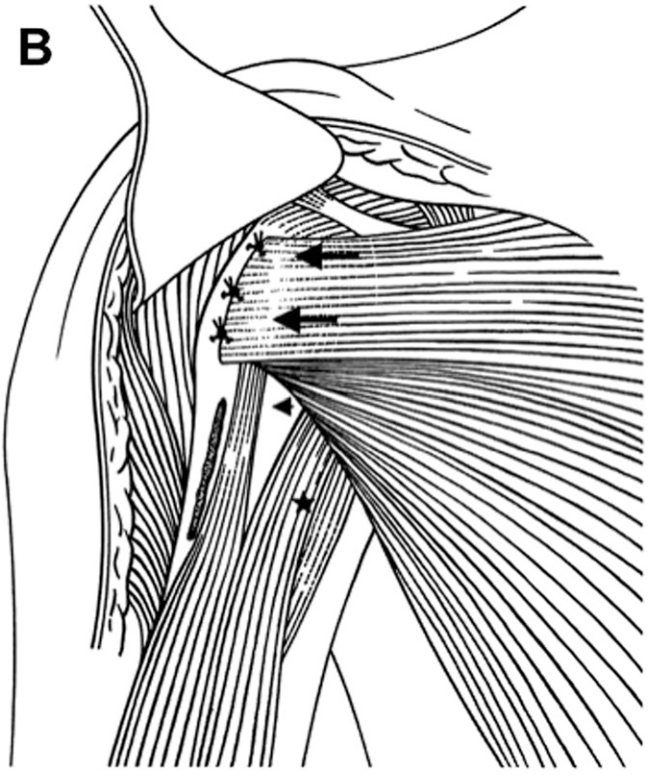

Fig. 1-B

Figs. 1-A and 1-B Schematic views of the surgical technique on a right shoulder. Reproduced from: Jost B, Puskas GJ, Lustenberger A, Gerber C. Outcome of pectoralis major transfer for the treatment of irreparable subscapularis tears. J Bone Joint Surg Am. 2003;85(10):1944-51. **Fig. 1-A** The deltoid muscle is retracted. After mobilization of the subscapularis, an attempt is made to repair the remaining tendon, scar, and fascial tissue (arrowheads) to the lesser tuberosity. The pectoralis major tendon (arrows) is then released completely from its insertion (dashed line). A reinsertion area for the pectoralis major tendon on the medial aspect of the greater tuberosity is then prepared (asterisk). **Fig. 1-B** The pectoralis major tendon (arrows) is transferred to the medial aspect of the greater tuberosity over the conjoined tendon (asterisk). The long head of the biceps is indicated by the arrowhead.

patients with irreparable subscapularis tears, with or without involvement of the posterosuperior rotator cuff[11-13].

To our knowledge, longer-term results of PMT have only been reported for irreparable anterosuperior lesions with a follow-up of 10 years[14]. It was therefore the purpose of the present study to report the longer-term clinical and imaging outcomes of PMT for irreparable subscapularis tears with or without involvement of the supraspinatus tendon, the early results of which have previously been published[11]. It was hypothesized that there would be a significant clinical deterioration between the short-term and the 20-year results, with high rates of advanced osteoarthritis and revision operations.

Materials and Methods

Ethics board approval was obtained, and all included patients gave written consent for the study.

Patients

We identified 30 consecutive primary PMTs performed between 1995 and 1999 for the treatment of irreparable subscapularis tendon tears in 26 men (2 bilaterally) and 2 women with an average age of 53.0 years (range, 35 to 67 years). A tear was considered irreparable if preoperative retraction of the subscapularis musculotendinous unit was beyond the glenoid rim and if the fatty infiltration of the subscapularis muscle was of grade III or IV according to the magnetic resonance imaging (MRI) adaptation of the Goutallier classification[15,16]. The dominant arm was involved in 20 cases (67%). Twenty-five shoulders (83%) had an history of trauma, and 5 had no trauma documented. Twelve shoulders (40%) underwent a total of 16 previous surgical procedures, including 11 failed rotator cuff repairs, of which 7 were failed subscapularis repairs. As all tears were chronic and longstanding with fatty infiltration of the subscapularis, nonoperative treatment had been attempted for 6 months in all cases.

At the time of the latest follow-up, 5 patients representing 5 shoulders (17%) had died unrelated to the PMT, and 1 patient representing 1 shoulder (3%) had been lost to follow-up. Of the 5 patients who had died, 1 patient had undergone a revision procedure with refixation of the primary PMT because of a nontraumatic anchor avulsion 10 months postoperatively. For this patient, the final relative Constant score (CS) at 2 years after revision was 25%, constituting a poor outcome. None of the remaining patients had any complications or revision

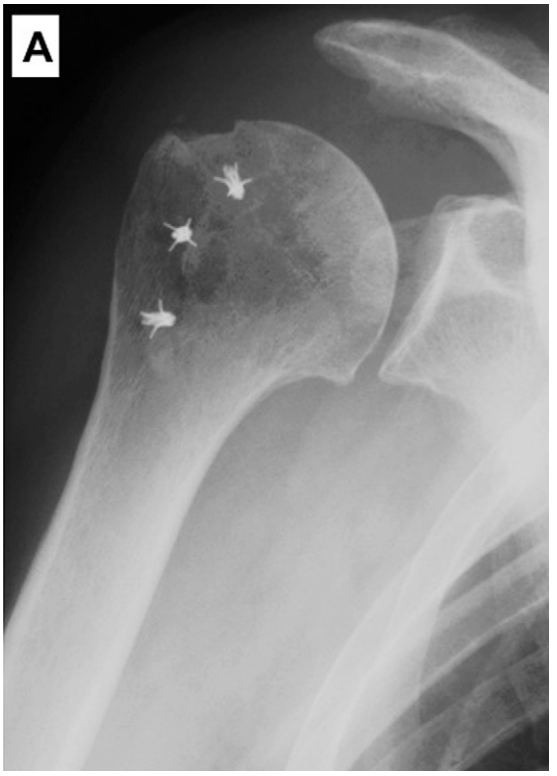

Fig. 2-A

Fig. 2-B

Figs. 2-A and 2-B Failed PMT with advanced glenohumeral arthritis 19 years postoperatively. **Fig. 2-A** Anteroposterior radiograph made immediately postoperatively showing anchor placement of the PMT medial to the greater tuberosity. **Fig. 2-B** Anteroposterior radiograph made 19 years postoperatively showing advanced glenohumeral arthritis.

procedures, as confirmed by institutional records or telephone interviews with family members.

Thus, the final cohort consisted of 24 shoulders in 22 patients (20 men and 2 women) with a mean age of 52.4 years (range, 35 to 67 years) at the time of PMT. Patients were personally interviewed and examined at a mean of 19.7 years (range, 18 to 22 years) postoperatively. In 10 shoulders (42%), the tear was limited to the subscapularis tendon. Ten shoulders (42%) had a tear involving the subscapularis and supraspinatus tendons (Goutallier grades I to III), and 4 (17%) had a tear of the subscapularis, supraspinatus (Goutallier grades; range, I to III), and infraspinatus tendons (Goutallier grades I to II). According to intraoperative findings[11], 8 shoulders (33%) were found to have an irreparable supraspinatus tendon. Therefore, 3 groups were defined: isolated subscapularis tear (group 1; n = 10), massive tear with a reparable supraspinatus tear (group 2; n = 6), and massive tear with an irreparable supraspinatus tear (group 3; n = 8).

Surgical Technique

All surgical procedures were performed or supervised by the senior author (C.G.). PMT was carried out if the tears were irreparable and functionally disabling. The final decision for the transfer was made intraoperatively. The PMT was performed according to the technique described in the previous article by Jost et al.[11] (Fig. 1). The key steps consisted of (1) attempting to repair the remaining subscapularis tendon/scar, (2) releasing the entire PMT, (3) transferring the PMT over the conjoined tendon, and (4) reinserting the PMT on the medial aspect of the greater tuberosity. In the presence of an isolated subscapularis tear, a sling was used for 6 weeks. Patients with a massive tear wore an abduction brace for 6 weeks postoperatively. Shoulder passive range-of-motion exercises were begun immediately postoperatively in internal rotation. Active range-of-motion exercises started 6 weeks postoperatively, and strengthening, after 12 weeks.

Clinical and Imaging Assessment

Functional and imaging results were not included for the single patient who had undergone joint replacement. Two patients did not consent to an imaging examination and were therefore included for functional assessment only. Clinical and imaging examination were performed preoperatively and postoperatively at short-term follow-up after a mean of 2.7 years (range, 2 to 6 years)[11] and at the time of the latest follow-up (mean, 20 years).

Clinical assessment was performed by an examiner (S.C. or L.E.) different from the operating surgeon and included assessment of ranges of motion with use of a handheld goniometer with the patient seated and assessment of the CS (both

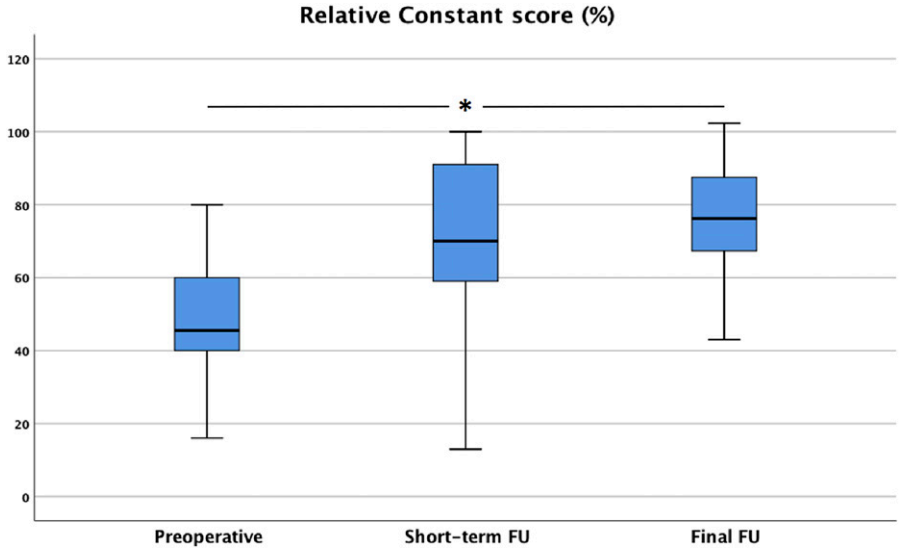

Fig. 3

The CS% over time with the top and bottom of each box indicating the interquartile range, the line within each box indicating the median, and the whiskers representing 1.5 standard deviations of the box. There was significant improvement (*) from the preoperative state to the latest follow-up ($p < 0.001$). FU = follow-up.

absolute [aCS] and as a percentage of age and sex-matched normal scores [CS%])[17] and the Subjective Shoulder Value (SSV)[18]. The function of the subscapularis was assessed with use of the lift-off test[3]. Patients rated the overall postoperative results as "excellent," "good," "fair," or "unsatisfactory." Abduction strength was measured with use of a validated electronic dynamometer (Isobex; Cursor)[4].

All shoulders underwent preoperative and postoperative imaging with standardized true anteroposterior, axillary lateral, and scapular lateral radiographs. Radiographs were evaluated for glenohumeral osteoarthritis according to the Samilson and Prieto classification[19] for glenohumeral arthropathy, the Hamada classification[20] for cuff tear arthropathy, and the modified Walch classification[21,22] for posterior and anterior humeral head subluxation[11]. At the latest follow-up, ultrasound examination (ACUSON S3000 ultrasound system; Siemens Healthcare) with a linear array transducer (bandwidth, 4 to 9 MHz) was performed by a senior musculoskeletal radiologist,

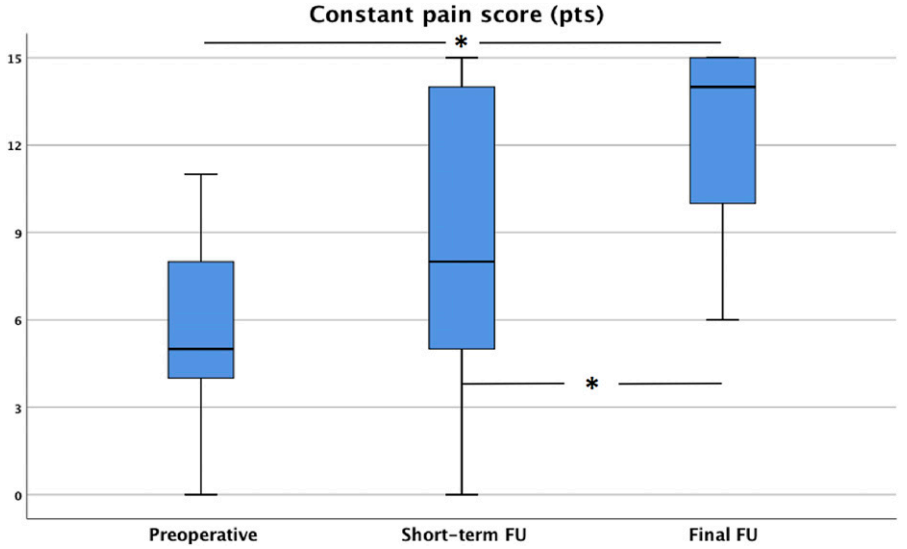

Fig. 4

The CS pain score (in points) over time with the top and bottom of each box indicating the interquartile range, the line within each box indicating the median, and the whiskers representing 1.5 standard deviations of the box. There was significant improvement (*) from the preoperative state to the latest follow-up ($p < 0.001$) and from the short-term follow-up to the latest follow-up ($p = 0.003$). FU = follow-up.

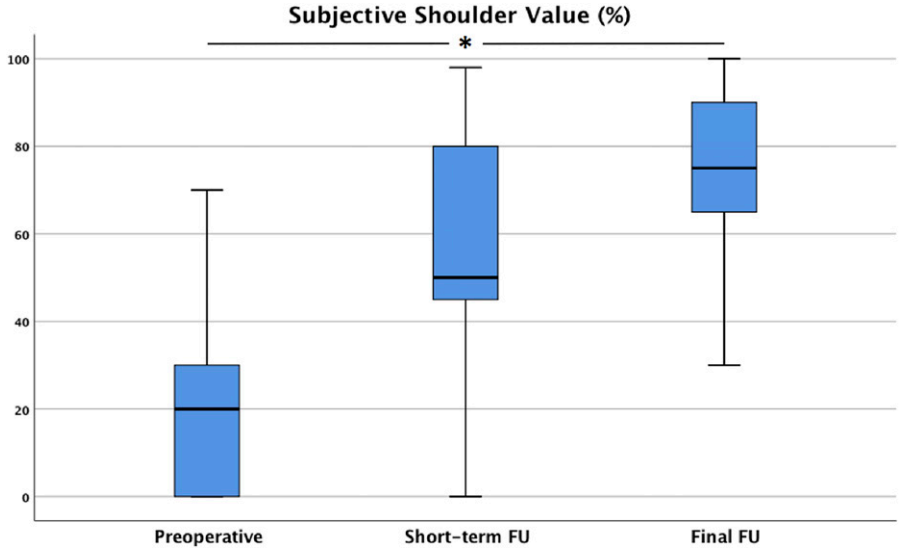

Fig. 5

The SSV (in %) over time with the top and bottom of each box indicating the interquartile range, the line within each box indicating the median, and the whiskers representing 1.5 standard deviations of the box. There was significant improvement (*) from the preoperative state to the latest follow-up ($p < 0.001$). FU = follow-up.

and the integrity of the PMT was assessed according to the Sugaya classification[23]. The imaging data were analyzed by the radiologist and an orthopaedic surgeon, who were both blinded to the clinical results.

Statistical Analysis

Normality of the distribution was tested with use of the Shapiro-Wilk test. Preoperative and postoperative scores were compared with use of the paired t test (for normal data) or the Wilcoxon signed-ranks test (for non-normal data). The Mann-Whitney U test was used for subgroup analysis to assess the influence of humeral head subluxation and the influence of different tear patterns of the 3 pre-defined groups. The Fisher exact test was used for categorical variables. Significance was set at 0.05, and all p values were 2-tailed.

Interobserver reliability of the glenohumeral osteoarthritic changes according to the Samilson and Prieto classification[19], the Hamada classification[20], and the modified Walch

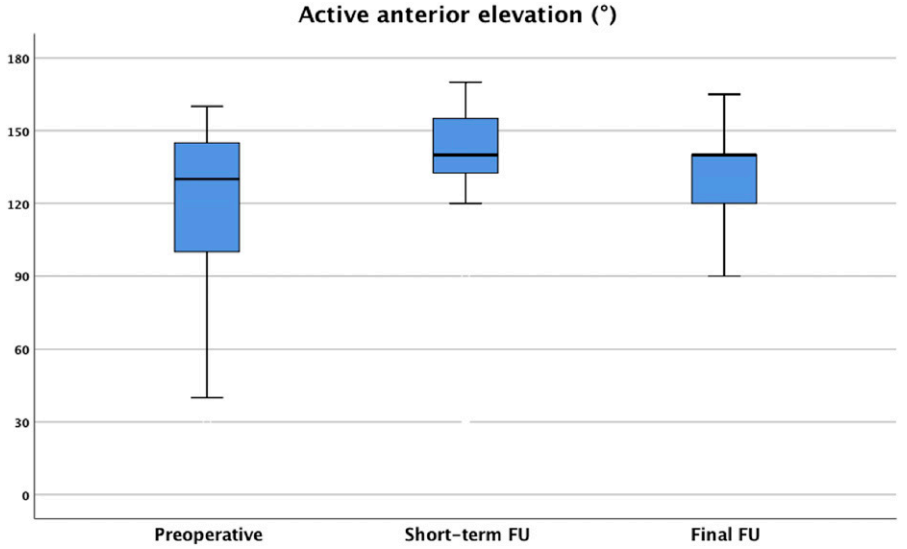

Fig. 6

The active anterior elevation (in °) over time with the top and bottom of each box indicating the interquartile range, the line within each box indicating the median and the whiskers representing 1.5 standard deviations of the box. There was no significant improvement from the preoperative state to the latest follow-up, but also no significant decline from the short-term follow-up to the latest follow-up. FU = follow-up.

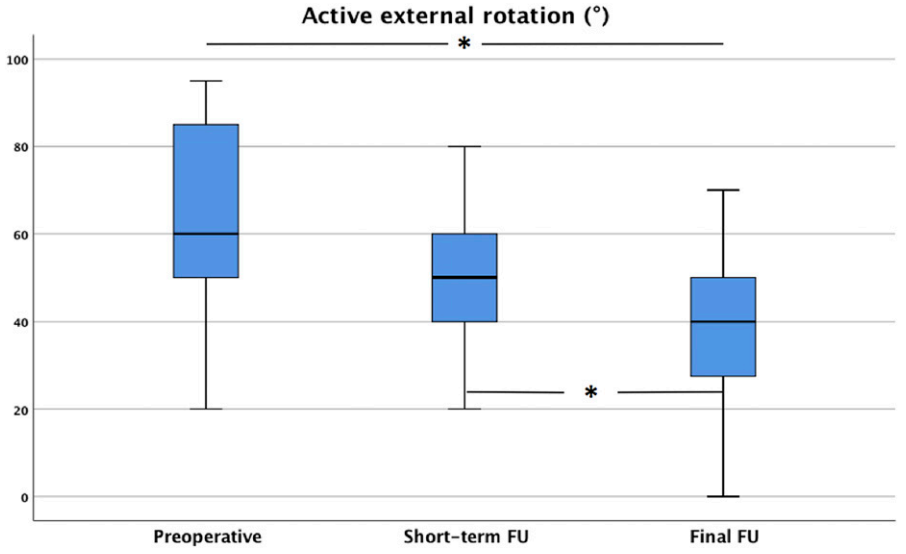

Fig. 7

The active external rotation (in °) over time with the top and bottom of each box indicating the interquartile range, the line within each box indicating the median, and the whiskers representing 1.5 standard deviations of the box. There was significant decline (*) from the preoperative state to the latest follow-up ($p < 0.001$) and from the short-term follow-up to the latest follow-up ($p = 0.002$); however, the mean active external rotation was still 39° at the time of the latest follow-up. FU = follow-up.

classification[21,22] was measured with use of the intraclass correlation coefficient (ICC) for absolute agreement, with 1 indicating perfect reliability.

Results

Complications and Reoperations

A total of 6 shoulders (20%) underwent reoperation, 1 of which required reoperation twice. The 2 patients who had a shoulder with nontraumatic avulsion of the PMT underwent open revision of the transfer. At the time of final follow-up, 1 of those 2 patients had died and the other was pain-free (CS%, 83%). One shoulder with an irreparable rerupture of the supraspinatus and infraspinatus underwent arthroscopic debridement. The patient reported slight pain (CS%, 54%) at the time of the latest follow-up. One patient with subcoracoid impingement underwent coracoplasty and had good shoulder

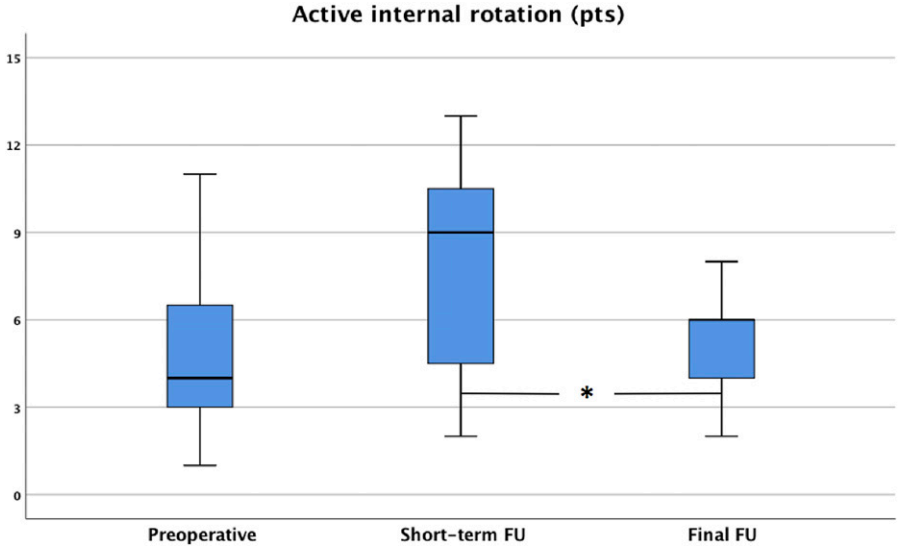

Fig. 8

The active internal rotation (in points) over time with the top and bottom of each box indicating the interquartile range, the line within each box indicating the median, and the whiskers representing 1.5 standard deviations of the box. There was significant decline (*) from the short-term follow-up to the latest follow-up ($p = 0.005$). FU = follow-up.

TABLE I Clinical* and Radiographic† Findings Preoperatively and at Short-Term (2 to 6 Years) and Final Follow-up (18 to 22 Years)†

Variable	Preop.	Short-Term Follow-up	Latest Follow-up	P Value (Preop. Vs. Latest Follow-up)	P Value (Short-Term Vs. Latest Follow-up)
CS					
Absolute *(points)*	42 ± 15	63 ± 21	64 ± 13	<0.001	0.834
Relative *(%)*	47 ± 17	71 ± 23	77 ± 15	<0.001	0.199
Pain *(points)*	5 ± 3	9 ± 5	13 ± 3	<0.001	0.003
Strength *(points)*	3.4 ± 3.1	8.3 ± 6.5	5.5 ± 4.9	0.439	0.004
SSV *(%)*	22 ± 20	59 ± 28	71 ± 25	<0.001	0.093
Range of motion					
AAE *(°)*	120 ± 38	135 ± 33	131 ± 24	0.133	0.406
Abduction *(°)*	104 ± 39	130 ± 33	126 ± 28	0.009	0.554
External rotation *(°)*	65 ± 21	51 ± 16	39 ± 18	<0.001	0.002
Internal rotation *(points)*	5 ± 3	8 ± 4	6 ± 2	0.286	0.005
Satisfaction, no. (%)					
Excellent		14 (61%)	18 (78%)	NA	NA
Good		7 (30%)	5 (22%)	NA	NA
Fair		0	0	NA	NA
Unsatisfactory		2 (9%)	0	NA	NA
Dislocation arthropathy§	0.4 ± 0.6	0.5 ± 0.6	1.2 ± 1.2	0.001	0.003
Cuff tear arthropathy#	1.0 ± 0.0	1.1 ± 0.4	1.6 ± 1.0	0.009	0.004

*23 shoulders; postoperative clinical results exclude the patient with an RTSA. †21 shoulders; postoperative imaging results exclude the patient with an RTSA and the 2 patients who declined imaging assessment. ‡The values are given as the mean and standard deviation unless otherwise noted. AAE = active anterior elevation, and NA = not applicable. §Dislocation arthropathy was graded from 1 (mild) to 3 (severe) according to the Samilson and Prieto classification[19]. #Cuff tear arthropathy was graded from 1 (no degeneration) to 5 (cuff tear arthropathy) according to the Hamada classification[20].

function (CS%, 74%) at the time of the latest follow-up. One patient with an infection underwent open debridement and antibiotic treatment but later developed severe and painful osteoarthritis, eventually undergoing reverse total shoulder arthroplasty (RTSA) (Fig. 2). The 1 remaining shoulder developed recurrent anterior subluxation and underwent arthroscopic Bankart repair and biceps tenotomy without overt instability until the latest follow-up, but continued to have moderate pain (CS%, 43%).

In the group with an isolated subscapularis tear (group 1), 2 (20%) of the 10 shoulders underwent revision: 1 coracoplasty and 1 ultimate RTSA. In the group with a concomitant reparable supraspinatus tear (group 2), 1 (17%) of 6 shoulders underwent arthroscopic rotator cuff debridement. In the group with a concomitant irreparable supraspinatus tear (group 3), 2 (25%) of the 8 shoulders underwent revision: 1 open PMT refixation and 1 arthroscopic Bankart repair.

Clinical Outcome

The 1 shoulder revised to RTSA was not included in the analysis of the clinical results.

For the remaining 23 shoulders, there was significant improvement in the mean aCS ($p = 0.001$) and CS% ($p < 0.001$), pain ($p < 0.001$), and SSV ($p < 0.001$) compared with the preoperative state, which did not significantly deteriorate from short-term to latest follow-up (Figs. 3 through 8; Table I). Although active anterior elevation remained unchanged ($p = 0.133$), active abduction was significantly improved compared with the preoperative state ($p = 0.009$). Active external rotation significantly deteriorated over time ($p = 0.002$) compared with the preoperative state ($p < 0.001$), but still averaged 39° at the time of the latest follow-up. Internal rotation was significantly improved at short-term follow-up (8 points) compared with the preoperative state (5 points; $p < 0.001$), but nearly dropped to the preoperative level at the time of the latest follow-up (6 points; $p = 0.286$). Active external and internal of the contralateral side were also significantly less at the time of the latest follow-up compared with the preoperative measurements (42° and 7 points compared with 65° and 9 points, respectively; $p < 0.001$ and $p = 0.002$, respectively). The lift-off test was positive preoperatively in all 24 shoulders and remained positive in 15 (65%) of the 23 shoulders included in the clinical analysis. All patients rated their overall postoperative outcome as good (n = 5) or excellent (n = 18).

There were no significant differences in any clinical outcome parameter when comparing patients with an isolated subscapularis tear (group 1; n = 9) to those with a concomitant reparable supraspinatus tear (group 2; n = 6) or those with a

TABLE II Comparison of Clinical Findings in the 3 Subgroups at the Time of Latest Follow-up (18 to 22 Years)*

Variable	Isolated SSC Tear (N = 9)		Combined SSC + Reparable SSP Tear (N = 6)		Combined SSC + Irreparable SSP Tear (N = 8)	
	Mean ± SD	P Value†	Mean ± SD	P Value‡	Mean ± SD	P Value§
CS						
Absolute *(points)*	62 ± 12	0.479	66 ± 17	0.516	64 ± 13	0.500
Relative *(%)*	75 ± 14	0.480	80 ± 17	0.519	76 ± 16	0.501
Pain *(points)*	13 ± 3	0.533	14 ± 2	0.408	12 ± 4	0.533
Strength *(points)*	4.4 ± 7.0	0.330	7.7 ± 6.9	0.361	5.1 ± 4.2	0.376
SSV *(%)*	62 ± 30	0.138	85 ± 13	0.216	71 ± 22	0.594
Range of motion						
AAE *(°)*	133 ± 14	0.806	120 ± 37	0.433	136 ± 22	0.550
Abduction *(°)*	124 ± 24	0.906	121 ± 37	0.846	133 ± 27	0.494
External rotation *(°)*	32 ± 20	0.060	50 ± 11	0.089	38 ± 16	0.436
Internal rotation *(points)*	6 ± 2	0.622	5 ± 2	0.890	5 ± 2	0.481

*Postoperative results exclude the patient with an RTSA. SSC = subscapularis, SSP = supraspinatus, SD = standard deviation, and AAE = active anterior elevation. †Compared with combined SSC and reparable SSP tears. ‡Compared with combined SSC and irreparable SSP tears. §Compared with isolated SSC tear.

concomitant irreparable supraspinatus tear (group 3; n = 8). There were also no significant clinical differences between groups 2 and 3 (Table II).

The short-term clinical outcomes of the 6 patients lost to follow-up were similar to the short-term outcomes of the 23 shoulders followed for a mean of 20 years.

Imaging Outcome

The 1 patient who underwent RTSA and the 2 patients who declined imaging assessment were not included in the analysis of the imaging results.

Of the remaining 21 shoulders, 4 (19%) showed evidence of glenohumeral arthropathy (Samilson and Prieto grade 3), but were clinically mildly symptomatic or asymptomatic at the time of the latest follow-up (CS% range, 67% to 88%; Constant pain score range, 10 to 15 points; SSV range, 70% to 80%). Another 2 shoulders (10%) showed evidence of cuff tear arthropathy greater than Hamada stage 3, and these were the only shoulders with a sonographically verified tear of the PMT. In the other 19 shoulders, ultrasound examination revealed an intact transfer. Although significant, there was no relevant progression in the mean arthropathy stage from preoperatively to the latest follow-up (Hamada[20] stages, 1.0 compared with 1.6, respectively; p = 0.009; and Samilson and Prieto[19] stages, 0.4 compared with 1.2, respectively; p = 0.001) in the 21 patients (Table I). Posterior humeral head subluxation was observed in 2 shoulders (10%), and anterior humeral head subluxation, in 3 shoulders (14%).

There were no significant differences in final arthropathy stage (glenohumeral arthropathy according to Samilson and Prieto and cuff tear arthropathy) when comparing patients with an isolated subscapularis tear (group 1; n = 9) to those with a concomitant reparable supraspinatus tear (group 2; n = 4) or those with a concomitant irreparable supraspinatus tear (group 3; n = 8). There were also no significant differences between groups 2 and 3.

The interobserver reliability for glenohumeral arthropathy according to Samilson and Prieto (ICC = 0.85; 95% confidence interval [CI], 0.63 to 0.94), cuff tear arthropathy (ICC = 0.87; 95% CI, 0.68 to 0.95), and anteroposterior humeral head subluxation (ICC = 0.88; 95% CI, 0.70 to 0.95) was very good.

Discussion

Long-term results after PMT remained good to excellent up to 22 years postoperatively. Furthermore, no relevant progression of osteoarthritic changes was observed, and radiographic signs of overt osteoarthritis remained clinically mildly symptomatic or asymptomatic. Only 1 (3%) of 30 shoulders required RTSA within a 20-year follow-up period.

Significant improvements in CS and pain were observed at the time of the latest follow-up. The results of the present study at 20 years postoperatively are comparable with those after 10 years in the study by Moroder et al., which included a series of 22 patients who underwent modified PMT for an irreparable anterosuperior rotator cuff tear[14]. In that cohort, the CS% and the Simple Shoulder Test remained stable between short-term and long-term follow-up. Also in the present study the CS values did not deteriorate over the longer term; however, abduction strength and active internal and external rotation did decrease compared with short-term results, although this decrease should be viewed in light of the fact that there was an average increase in patient age of approximately 17 years between the 2 follow-up examinations

and that a comparable decrease in active internal and external rotation was observed in the contralateral side over the observational period. Such changes in both operative and contralateral shoulders might be related to the weakness and degeneration associated with aging[24-27]. Furthermore, regardless of how the procedure is modified[12], PMT cannot usually compensate for weakness of the subscapularis at the end range of internal rotation; therefore, PMT cannot always correct a positive lift-off test or restore normal active overhead function[12-14]. Even despite the fact that PMT cannot compensate for such subscapularis weakness, objective and notably subjective postoperative improvement persisted over time, and the minor differences in function and pain between the operated shoulders and a normal shoulder were very well tolerated by patients despite the fact that two-thirds of shoulders were dominant, possibly because these patients had a very substantial disability before operation. With all 23 shoulders rated excellent or good and with an RTSA also rated as excellent, the outcome of PMT in the present study was clearly better than what we had hypothesized, and the fact that SSVs improved relevantly over time may speak for an adaptation of the patients to their potential.

At the short-term follow-up[11], clinical outcomes in shoulders with an isolated subscapularis tear were better than those in shoulders with a massive tear. Furthermore, shoulders with a massive tear in which the supraspinatus could be soundly repaired had significantly better results than shoulders with a massive tear in which the supraspinatus tear was irreparable[11]. These differences associated with the quality of the preoperative supraspinatus tendon were negligible 20 years postoperatively; the reasons for this finding are not known. Surprisingly, advanced cuff tear arthropathy was observed in only 2 patients in whom the fixation of the transfer had failed.

In three-fourths of the included patients, the humeral head remained centered on static radiographs at 20 years postoperatively. There was also no relevant progression of cuff tear arthropathy.

The results of the present study contrast with those reported by Resch et al.[12], who noted advanced cuff tear arthropathy in one-fourth of cases treated with the modified, partial (abdominal and sternocostal portions) subcoracoid PMT on long-term follow-up[14]. This discrepancy between results might be a consequence of more severe rotator cuff tear involvement in the study by Resch et al., as all patients had an associated supraspinatus tear and one-third had a tear that extended into the infraspinatus (compared with 17% in the present study). The differences might also be a result of the differing surgical technique and/or selection bias.

This study had limitations, including the biases associated with the retrospective design, the patients lost to follow-up (3%) and those who died (17%), and the limited power to perform meaningful subgroup analysis. A follow-up rate of 80% of all patients who underwent PMT at our institution 20 years ago makes this study a meaningful contribution to the limited knowledge about long-term outcomes of tendon transfers for irreparable rotator cuff tears.

PMT for an irreparable subscapularis tear is associated with a low failure rate, but had a relatively high reoperation rate, with minor revisions not associated with adverse outcomes. Subjective outcomes were good to excellent at 20 years postoperatively, with mostly mildly symptomatic or asymptomatic osteoarthritis in 29% of the cases. Our experience suggests that patients with irreparable, isolated subscapularis tears and preserved active shoulder elevation are good candidates for the transfer described in the present study. Patients with concurrent reparable supraspinatus tears are also good candidates, with excellent subjective long-term outcomes. If a subscapularis tear is associated with chronic pseudoparalysis of anterior elevation and dynamic or static anterosuperior escape, we do not use this procedure and would prefer alternatives such as RTSA. ■

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